LDCM

Landsat Data Continuity Mission

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by

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Topics



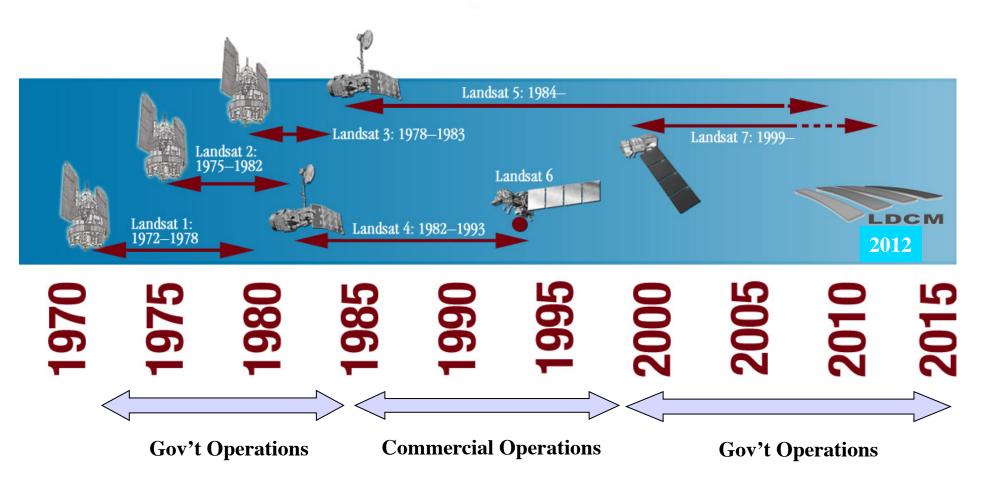
- Background
- LDCM Mission Overview
- Mission Life Cycle Status
- NASA/USGS Partnership
- Schedule
- Mission Status
 - Operational Land Imager
 - Thermal Infrared Sensor
 - Spacecraft
 - Mission Operations Element and Operations
 - Launch Vehicle
- LDCM Data Products

LDCM

Background

History of the Landsat Program





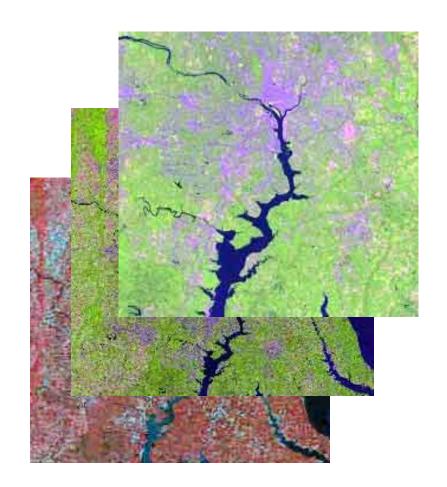
38-yr Landsat Data Archive

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Data are archived and distributed by USGS EROS Center, Sioux Falls, SD Over 2 million scenes in the archive

As of February 28, 2010

- ETM+: Landsat 7
 - 1,016,250 scenes
 - 944TB
 - Archive grows by 260 GB Daily
- TM: Landsat 4 & Landsat 5
 - 848,429 scenes
 - 212TB
 - Archive Grows by 40 GB Daily
- MSS: Landsat 1 through 5
 - 513,866 scenes
 - 15 TB of Data



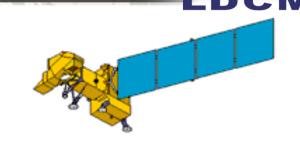
Data Policy Revolution



- USGS EROS has historically distributed Landsat data products to the general public on a non-discriminatory basis at the "cost of fulfilling a user request (COFUR)"
 - \$600 per Landsat 7 ETM+ scene
- April 21, 2008 USGS Technical Announcement:
 - "By February 2009, any Landsat archive scene selected by a user will be processed, at <u>no charge</u>, automatically to a standard product recipe and staged for electronic retrieval."
- Data distribution rate increased by a factor greater than 60
 - EROS began distributing free Landsat data on Oct. 01, 2008
 - EROS distributed 1.1 M free scenes by Oct. 01, 2009 and passed 2M scenes by March 13, 2010
 - Previous annual maximum distribution was 20,000 scenes in 2001

Landsat 7 & Landsat 5 Status

- Landsat 7 6 years beyond design life
 - 1999 Launch
 - Spacecraft
 - Gyro 3 Failure (Shut down May 5, 2004)
 - Working additional improvements for software gyro
 - Other Spacecraft Issues (non-critical)
 - Solid State Recorder 4 memory boards
 - Electrical Power Subsystem shunt #14 and shunt #6
 - Fuel Line Thermostat
 - ETM+
 - Scan Line Corrector Failure (May 31, 2003)
 - Bumper Mode Operations (April 1, 2007)
- Landsat 5 23 years beyond design life
 - 1984 Launch
 - Spacecraft
 - Battery 2 Anomaly (On-going) Oct 2007
 - Star Tracker Issue June 2007
 - Solar Array Drive
 - Fixed array operations Aug 2006
 - TM
 - Functioning normally in bumper-mode
 - Current Travelling Wave Tube Amplifier (TWTA) problems

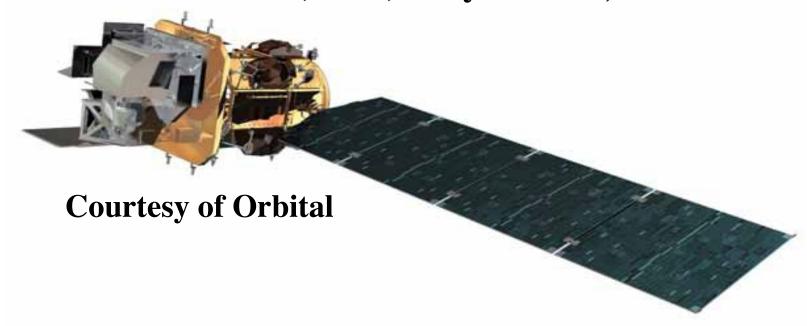




Future Landsat Data



- ➤ The Landsat Data Continuity Mission (LDCM) is under development for a December, 2012 launch
 - Developed as a NASA / USGS partnership
 - LDCM conducted a successful critical design review (CDR) May 25 27, 2010



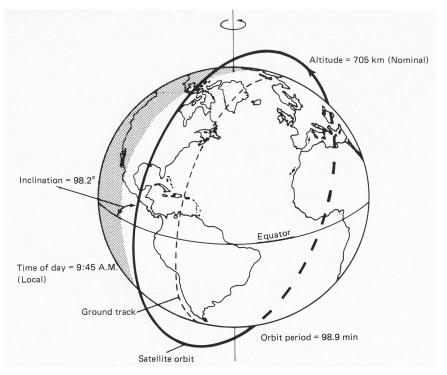


LDCM Mission Overview

Top Level Mission Ops Concept - Continuity

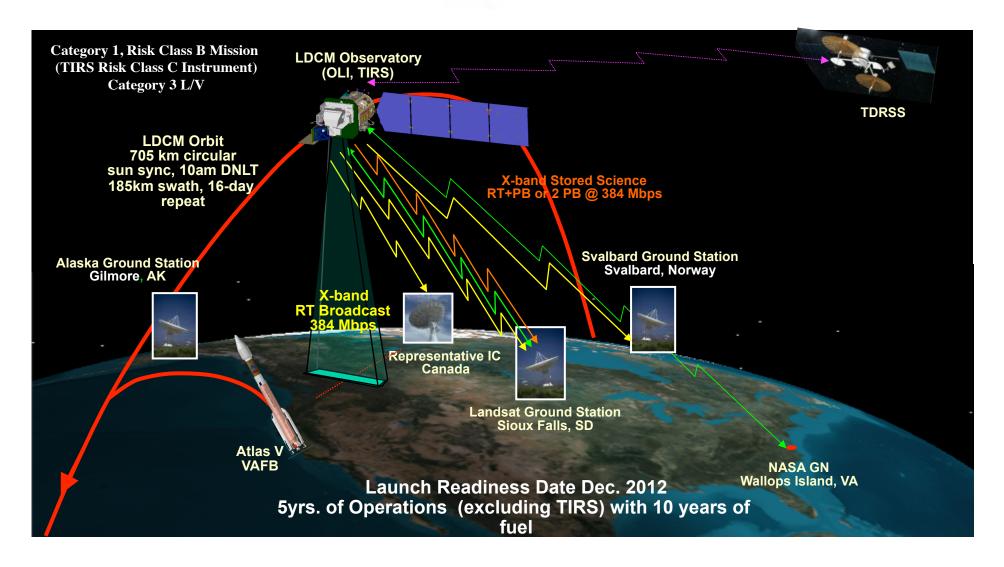
LDCM

- ➤ Fly LDCM observatory in legacy orbit (716 km, near-polar, sun-synchronous)
 - ➤ Ground tracks maintained along heritage WRS-2 paths with 10:00 a.m. equatorial crossing time
- ➤ Collect image data for multiple spectral bands (Vis/NIR/SWIR/TIR) across 185 km swath along each path
 - ➤ Provide coverage of global land mass each season by scheduling the collection of 400 WRS-2 scenes per day
 - > Maintain rigorous calibration
 - > Archive data and distribute data products
 - > Provide nondiscriminatory access to general public, generate Level 1 data products, distribute data products at no cost upon request
 - > Direct broadcast of data to network of international ground stations having memoranda-of-understanding with USGS



LDCM Overview





LDCM

Mission Life Cycle Status

Mission Life Cycle Status



- LDCM is a NASA Category 1 Mission
 - LDCM receives the highest level of visibility in NASA
 - Same as Hubble Space Telescope, Space Shuttle, Space Station, etc.
 - LDCM requires approval of the Agency Program Management Council to initiate each phase of the project lifecycle
 - An independent Standing Review Board evaluates the mission periodically (all mission level reviews) and makes recommendations to the Agency Program Management Council (both technical and programmatic)

Mission Life Cycle



- In December 2009, LDCM was "Confirmed"
 - NASA commits to US Congress cost and schedule for mission
 - Approval to proceed into Final Design and Fabrication portion of the Project Life Cycle
- In May 2010, LDCM completed its Mission Critical Design Review

LDCM in in Phase C

NASA Life Cycle Phases	Pre-Systems	FORMUL Acquisition	1,000	oval for nentation System	IMPLEI s Acquisition	MENTATION Operations	Decommissioning
Project Life Cycle Phases	Pre-Phase A: Concept Studies	Phase A: Concept & Technology Development	Phase B: Preliminary Design & Technology Completion	Phase C: Final Design & Fabrication	Phase D: System Assembly, Int & Test, Launch	Phase E: Operations & Sustainment	Phase F: Closeout
Project Life Cycle Gates & Major Events	KDP A FAD Draft Project Requirements	KDP B Preliminary Project Plain	KDP C Baseline Project Plan?	KDP D	V	MINCh End of Missi	Final Archival n of Data



NASA/USGS Partnership

NASA/USGS Responsibilities



NASA Responsibilities

- Space Segment, Launch Segment, and Mission Operations Element (MOE)
- Lead mission development as system integrator and lead missions systems engineering for all mission segments throughout development, on-orbit check-out, and acceptance
- Lead Mission Operations through completion of on-orbit checkout period
- Accountable for mission success through on-orbit check-out and acceptance across all mission segments

USGS Responsibilities

- Development of Ground System
 - Excluding the MOE
- Lead, fund, and manage the Landsat Science Team
- Lead LDCM mission operations, after the completion of the on-orbit checkout period
- Accept and execute all responsibilities associated with the transfer of the LDCM
 Operational Land Imager (OLI) instrument, spacecraft bus, Mission Operations
 Element, and NSC/KSAT contracts from NASA following on-orbit acceptance of
 the LDCM system including assuming contract management

NASA /USGS Mission Responsibilities

Space Segment

Operational Land Imager

Multi-Spectral Imaging Instrument Pushbroom VIS/SWIR sensor Four mirror telescope FPA consisting of 14 SCAs



Thermal Infrared Sensor

2 thermal channels Pushbroom design QWIP detectors Actively cooled FPA



Spacecraft

3-axis stabilized
Accommodated OLI & TIRS



Launch Segment

Atlas V 401



Ground System

Ground Network Element (GNE)

Antenna & associated equipment for X-Band image & S-Band telemetry data downlink reception and generation of S-Band command uplink

Collection Activity Planning Element (CAPE)
Generates high level imaging mission schedules

Mission Operations Element (MOE)

Mission planning & scheduling, command & control, monitoring and analysis, flight dynamics & onboard memory management

Data Processing and Archive System (DPAS)

User Portal Element (UPE)

Provides web interface to facilitate: data discovery, product selection & ordering (for Cal/Val), & product distribution

Storage and Archive Element (SAE)

Provides storage and services for data processing & archive services for data and archive products

Image Processing Element (IPE)

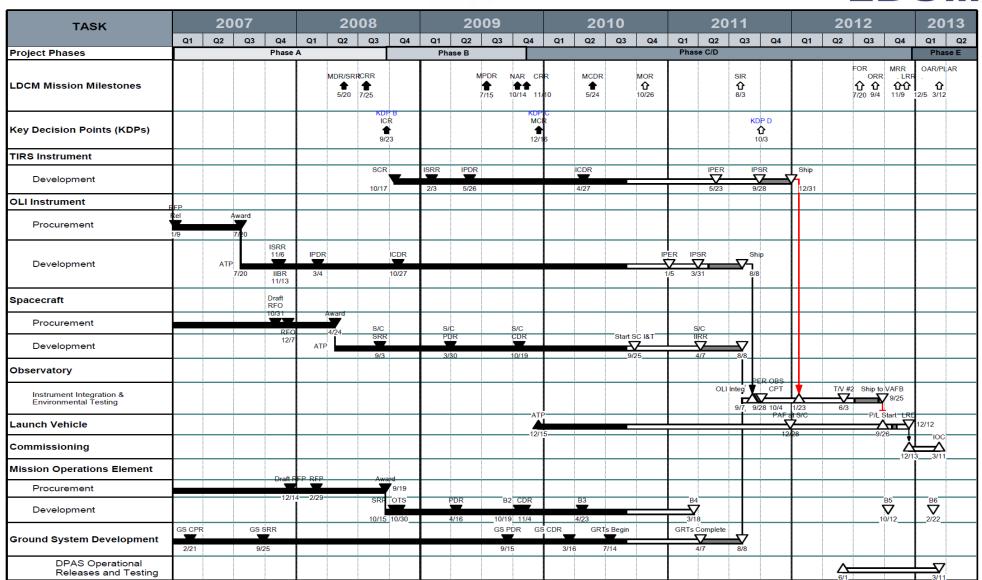
Provides: Ingest, Product Generation, & Image Assessment



Schedule

LDCM Master Schedule

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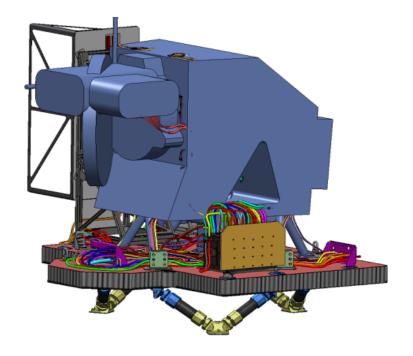
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Operational Land Imager

Operational Land Imager (OLI)



- OLI Provides
 - Accurate spectral and spatial information
 - Precise calibrated, geo-referenced data
- OLI Contains
 - Pushbroom VIS/NIR/SWIR detectors
 - Focal plane consisting of 14 Sensor Chip Assemblies (SCA) – 6,000 detectors per SCA for a total of 84,000 detectors
 - Visible and Short Wave Infrared Sensors
 - Four-mirror telescope
 - On-board calibration with both diffusers and lamps



OLI Spectral Bands

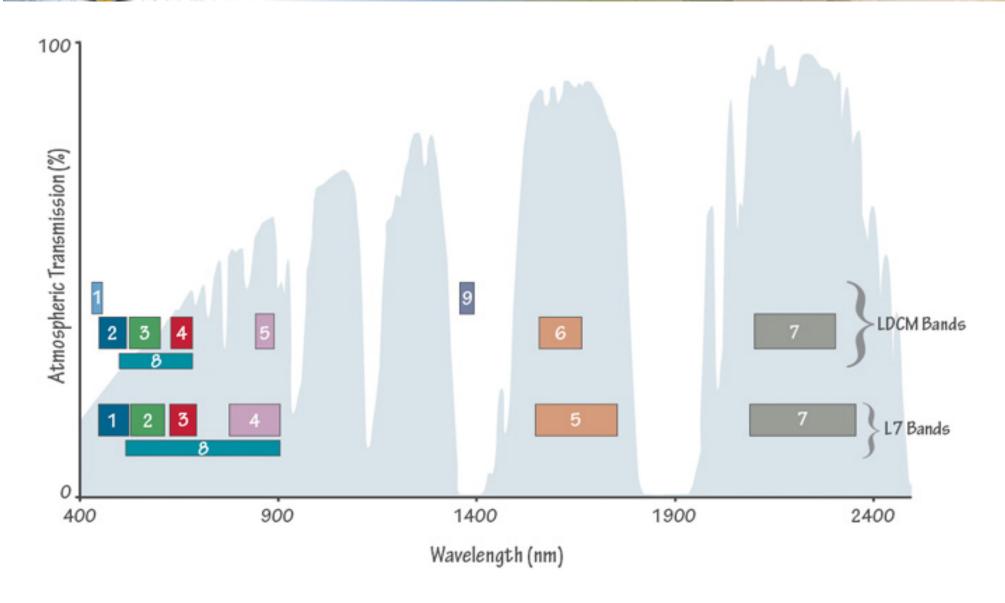


L7 ETM+ Bands		LDCM OLI Band Requirements			
		30 m Coastal/Aerosol	0.433 - 0.453 (2)	Band 1	
Band 1	30 m Blue 0.450 - 0.515	30 m Blue	0.450 - 0.515	Band 2	
Band 2	30 m Green 0.525 - 0.605	30 m Green	0.525 - 0.600	Band 3	
Band 3	30 m Red 0.630 - 0.690	30 m Red	0.630 - 0.680	Band 4	
Band 4	30 m Near-IR 0.775 - 0.900	30 m Near-IR	0.845 - 0.885	Band 5	
Band 5	30 m SWIR-1 1.550 - 1.750	30 m SWIR-1	1.560 - 1.660	Band 6	
Band 6	60 m LWIR 10.00 - 12.50	N/A	(3)		
Band 7	30 m SWIR-2 2.090 - 2.350	30 m SWIR-2	2.100 - 2.300	Band 7	
Band 8	15 m Pan 0.520 - 0.900	15 m Pan	0.500 - 0.680	Band 8	
		30 m Cirrus	1.360 - 1.390 (1)	Band 9	

• Explanation of Differences

- 1) Cirrus Band added in 2001 to detect cirrus contamination in other channels
- 2) Coastal Band added in 2001 at request of ocean color investigators requiring higher resolution of coastal waters relative to MODIS and SEAWifs
- 3) LWIR data to be collected by Thermal InfraRed Sensor (TIRS)
- 4) Bandwidth refinements made in all bands to avoid atmospheric absorption features
 - 1) Enabled by higher SNR which is, in turn, enabled by push-broom instrument architecture

OLI Spectral Bands



OLI and ETM+ Radiometric Performance

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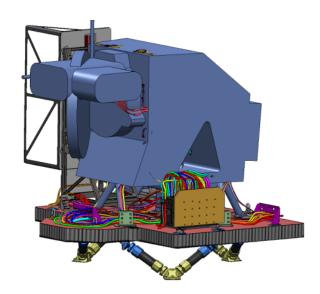
Signal-to-Noise Ratios (SNR)

	\mathbf{L}_{typics}	al SNR	L _{high} SNR		
Band	ETM+ Performance	OLI Requirements	ETM+ Performance	OLI Requirements	
Coastal/Aerosol	N/A	130	N/A	290	
Blue	40	130	140	360	
Green	40	100	190	390	
Red	30	90	140	340	
NIR	35	90	250	460	
SWIR 1	35	100	190	540	
SWIR 2	30	100	140	510	
Pan	16	80	90	230	
Cirrus	N/A	50	N/A	N/A	

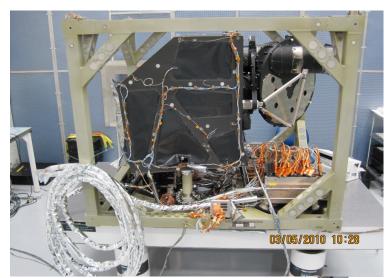
Operational Land Imager (OLI)



- OLI is currently in Integration and Test
 - Engineering Development Unit (EDU) testing complete and successful
 - EDU FPE, ISE, and FPA integrated with Flight Telescope
 - Telescope
 - Flight telescope complete and successfully tested
 - Focal Plane System
 - Flight Focal Plane System is complete and tested
 - Installed in flight telescope
 - Electronics
 - Flight Software
 - Complete and successfully tested
 - Flight Solar Calibration Assembly
 - Complete and in testing
 - Integrated Flight OLI functional testing initiated
 - All components integrated except Solar Calibration Assembly and Instrument Base Plate



Engineering Development Unit Configured Operational Land Imager







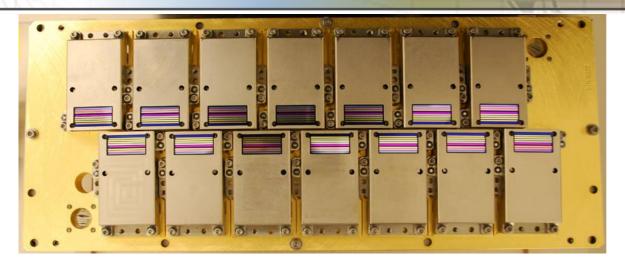
EDU Focal Plane/Flight
Telescope Integrated
with
EDU Focal Plane and
Instrument Support
Electronics

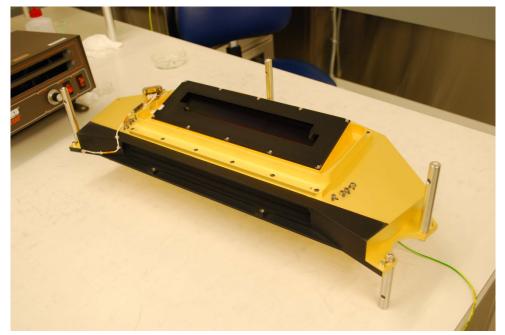


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Flight Focal Plane Assembly







Near-Term Plans



- Complete Flight OLI functional testing
- OLI Pre-Environmental Review in early January
- OLI Environmental Testing at the end of January
- OLI delivery to spacecraft at end of April 2011

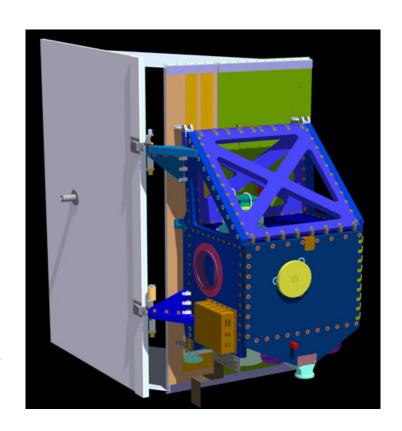
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Thermal Infrared Sensor (TIRS)

TIRS Overview

LDCM

- 2 channel (10.8 and 12 um) thermal imaging instrument
- Quantum Well Infrared Photodiodes (QWIP) / FPA built in-house at Goddard
- 100 m Ground Sample Distance
- 185 km ground swath (15° field of view)
- Operating cadence: 70 frames per second
- Pushbroom design with a precision scene select mirror to select between calibration sources
- Two full aperture calibration sources: onboard variable temp black body and space view
- Passively cooled telescope assembly operating at 180K
- Actively cooled (cryocooler) FPA operating at 43K
- 3 Year Design Life, Class C Instrument
- TIRS is being built in-house at NASA/GSFC
 - TIRS was officially added to the scope of the mission in December 2009
- Critical Design Review (CDR) completed April 2010



TIRS and ETM+ Spectral Bands



L7 ETM+ Thermal Band			LDCM TIRS Band Requirements		
Band 6	60 m LWIR	10.00 - 12.50	100 m LWIR	10.30 – 11.30	Band 10
			100 m LWIR	11.50 – 12.50	Band 11

- 120 m resolution TIRS requirement deemed sufficient to resolve most center-pivot irrigation fields in U.S. West - typically 400 to 800 m in diameter – TIRS design provides for 100 m resolution
- Landsat 4 & 5 TM's provided 120 m thermal images for a single thermal band
- Landsat 7 ETM+ provided 60 m thermal images for a single thermal band
- A two band instrument will enable atmospheric correction so that more accurate surface temperatures can be derived.

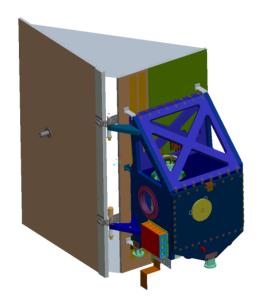
TIRS Status



- TIRS in fabrication and will start Integration and Test by end of 2010
 - Flight Focal Plane competed and successfully tested
 - Flight telescope is in assembly
 - Cryocooler
 - Flight build underway (built by BATC)
 - Focal Plane Electronics (FPE) in fabrication
 - Flight FPE in fabrication
 - Main Electronics Box (MEB) in fabrication

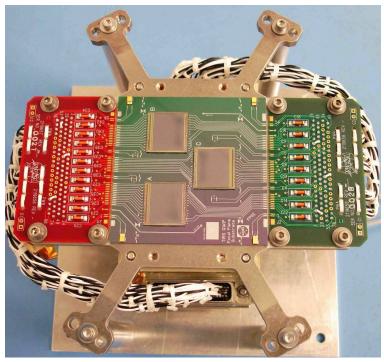


- FPM includes Engineering Model Telescope and Focal Plane
 - Eventually will include mechanisms and electronics
- FPM testing is a risk reduction strategy involving subsystem testing in a flight or flight-like configuration



TIRS Hardware Development

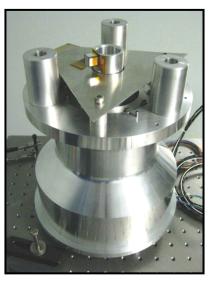




Flight Focal Plane Assembly



Engineering Model Cyrocooler



Engineering Model Scene Select Mechanism

Near Term Plans



- Flight I&T begins in early December
- Pre-Environmental Review May 2011
- TIRS delivery to spacecraft Oct. 2011

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Spacecraft



Spacecraft

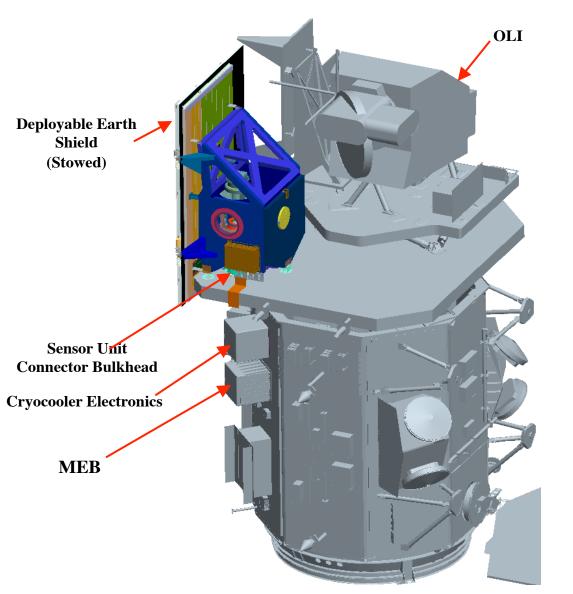


- Spacecraft
 - Accommodates two instruments (OLI, TIRS)
 - Provides pointing, power, data capacity, etc. to support LDCM operations
- Contract awarded to General Dynamics Advanced Information Systems (GDAIS) in April 08
 - GDAIS sold to Orbital Sciences Corporation in April 2010
- Spacecraft Integration Readiness Review completed August 2010

November 10, 2010

TIRS & OLI on LDCM Spacecraft







Spacecraft Status

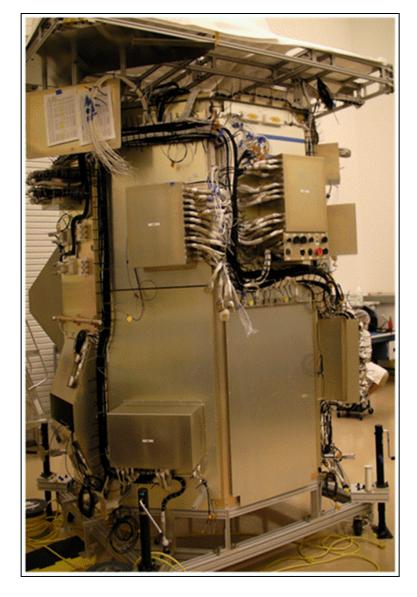


- S/C components in various levels of fabrication and test
 - All Engineering Model (EM) electronic boxes complete and tested
 - Flight electronics boxes in development and test
 - Spacecraft primary structure assembly complete and qualified
 - Flight harness complete and installed on structure
 - OLI and TIRS Interface Simulators tested with S/C Interface Simulator
 - Successful Testing of communication system with USGS ground support hardware

Flight Harness Completed on Spacecraft Mock-Up





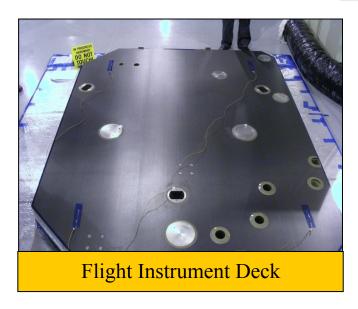


Structures and Mechanisms





Flight Structure with Solar-Array Support Brackets





Near Term Plans

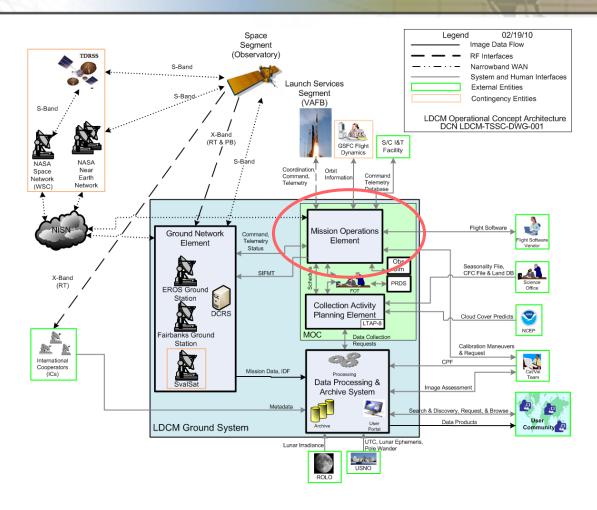


- Spacecraft Integration and Test
- Spacecraft ready for Observatory Integration and Test May 2011

Ground System Mission Operations Element and Operations

Ground System Architecture





•Mission Operations Element (MOE) – NASA

•Provides the primary means to control and monitor spacecraft

•Accomplishes mission planning and scheduling, command and control, monitoring and analysis, flight dynamics and onboard memory management

MOE Status



- MOE Contract (reimbursable from USGS) awarded to The Hammers Co. in September 08
- Mission Operations Element (MOE)
 - Three primary software builds have been completed and delivered to MOC
 - Over 90% of requirements implemented
 - Delivery and integration of mini-MOE at Orbital and successful interface test with Orbital softbench
- Operations
 - NASA responsible for mission operations through completion of on-orbit commissioning
 - USGS responsible for mission operations following commissioning through the life of the mission
 - Mission Operations Center
 - Mission Operations Center (MOC) is be at NASA/GSFC
 - MOC completed in November 2009

Operations Status



Flight Operations Team (FOT)

- Initiated staffing
 - Activities include
 - On-site presence at Orbital supporting early spacecraft I&T and procedure development
 - Supporting MOE
 - Supporting MOC integration
 - Developing operational documentation
 - Supporting ground readiness test planning

Ground Readiness Testing (GRT)

- Formal testing of the ground system
 - GRT #1 (of 6 total) successfully completed

LDCM Mission Ops Center







Launch Vehicle

Launch Vehicle



- Launch from Vandenberg Air Force Base on an Atlas V
- Interactions between Project, KSC, United Launch Alliance (ULA), and Orbital has begun



LDCM Data Products

Standard LDCM Data Products



- LDCM standard Level-1T data products will be consistent with heritage Landsat product specifications – backward compatibility
 - OLI and TIRS data will distributed as a combined product. Pixel size:
 15m/30m/30m
 - Quality Assurance (QA) "band" will be included
 - Media type: Electronic
 - Product type: Level-1T (precision, terrain correction)
 - Output format: GeoTIFF
 - Map projection: UTM (Polar Stereographic for Antarctica)
 - Orientation: North up
 - Resampling: Cubic convolution

Landsat Science Team & Advanced Products

Landsat Science Team



- USGS sponsors and convenes a Landsat Science Team
 - USGS solicited proposals for Science Team membership in 2006
 - Selection committee evaluated proposals
 - USGS selected 19 principal investigators (PI's) as Science
 Team members in October, 2006 for a period of 5 years
 - 8 U.S. federal civil servant PI's
 - 9 U.S. PI's from academia and private industry
 - 2 international PI's

Science Team Research



- Principal Investigators' research can roughly be divided into two related areas
 - Defining and developing the algorithms, data processing software, and prototypes necessary to define and generate advanced Landsat data products
 - Developing the computing capacity and methods necessary process large volumes of Landsat data for long-term and broad-area analyses and studies
 - This research and its rapid advancement have been enabled by the USGS policy of free data distribution

Advanced Landsat Data Products



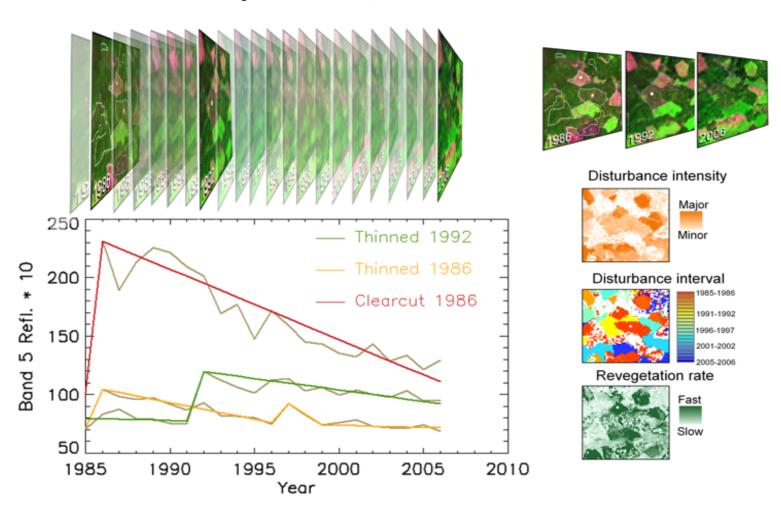
- Science Team goal is to define and develop advanced Landsat data products that can be routinely generated for open public access like Level 1T products
 - Cloud, cloud shadow, and water masks
 - Surface reflectance and surface temperature products
 - Essential climate variables
 - Land cover and land cover change maps
 - Biomass
- Representatives of Google.Org presented a novel concept for data product generation at the two most recent Team meetings
 - Google Earth Engine is a prototype on-line application that would allow clients to generate maps of deforestation and forest change using Landsat data based on software developed by Greg Asner of the Carnegie Institution

Atmospheric Correction LDCM **Landsat Ecosystem Disturbance Adaptive Processing System** Jeff Masek et al., NASA GSFC 1990's Landsat-5 mosaic **TOA** reflectance **Surface reflectance BOREAS Study Region** 100 km

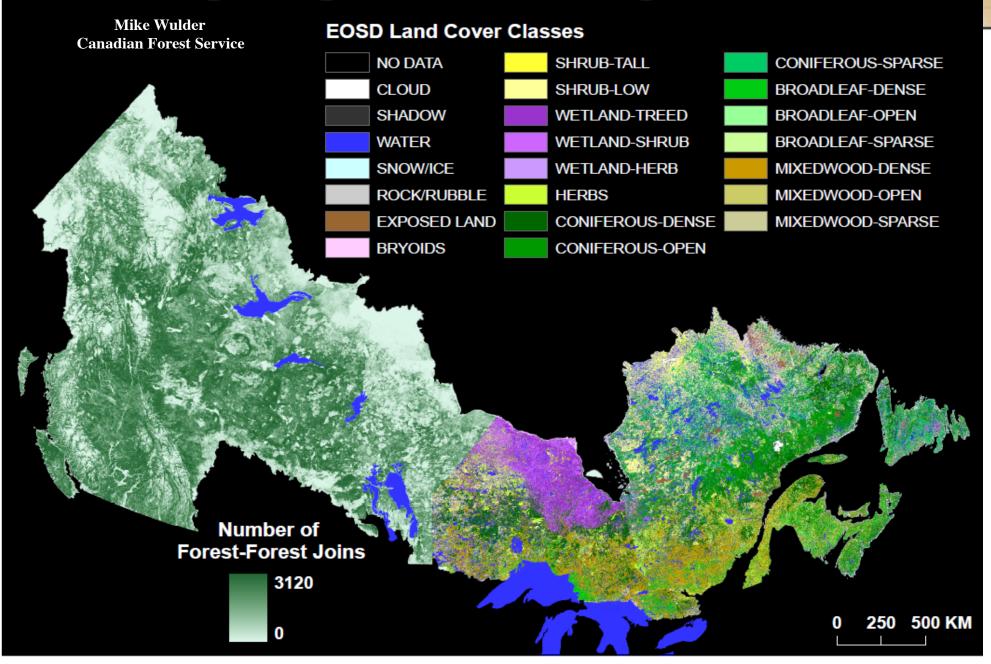
Impact of Free Data

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LandTrendr: Landsat-based Detection of Trends in Disturbance and Recovery – Kennedy and Cohen, Landsat Science Team - 2010



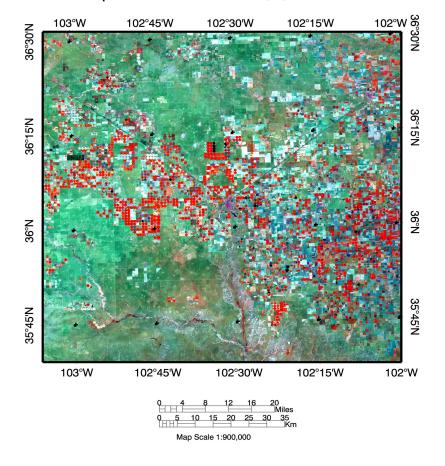
THE FORESTED AREA OF CANADA



Increase in Center Pivot Irrigation near Dalhart, TX

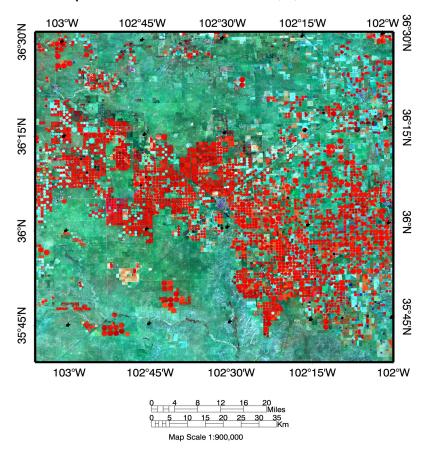
1989

p31r35 TM 7/8/89 4,5,3 RGB



1999

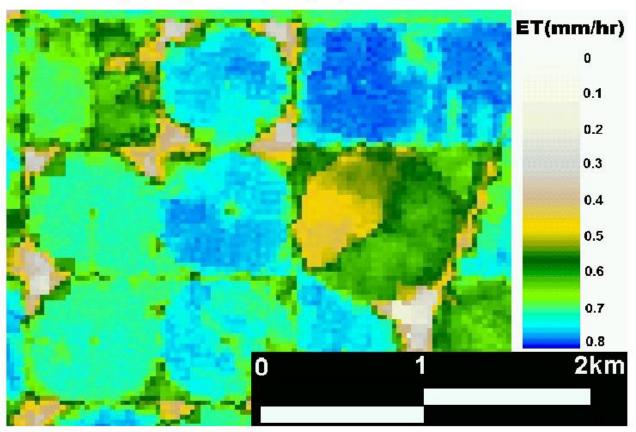
p31r35 ETM+ 8/13/99 4,5,3 RGB





Evapotranspiration at time of Landsat overpass

Oakley Fan, Idaho, July 7, 1989



Using 120 m Landsat 5 Thermal Data
Courtesy of Richard Allen, Kimberly Research and Extension Center, University of Idaho

Conclusion



- Continuity with previous Landsat missions is fulfilled by LDCM
 - LDCM data will be comparable to data from previous Landsat satellites
 - Data collection along heritage orbital paths with identical 185 km swath width
 - Ensure global coverage of land mass on seasonal basis
 - LDCM data will be backward compatible with data from previous Landsat sensors
 - Supports long term retrospective studies to trend change over time
- Capabilities are advanced
 - Two new reflective bands, refined band widths avoid atmospheric absorption features, two thermal bands facilitate atmospheric correction
 - Improved performance
 - More data 400 scenes per day lead to improved global coverage
- USGS will distribute LDCM data free to the general public
 - Capabilities to process and analyze large volumes of Landsat data are advancing rapidly for long term and broad area studies